# FINAL REPORT

# THERMOCAPILLARY CONVECTION IN FLOATING ZONES UNDER SIMULATED REDUCED-GRAVITY CONDISYIONS

by

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TITLE: Thermocapillary Convection in Floating Zones Under Simulated Reduced-

Gravity Conditions

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PRINCIPAL INVESTIGATOR: Sindo Kou

OBJECTIVE

The objective was to study thermocapillary convection in a transparent floating zone.

The floating zone process is a unique process for crystal growth in that the melt is free from contamination by a crucible. Microgravity is ideal for the floating zone process because there is no significant gravity to cause the molten zone to collapse as under normal gravity. Since gravity-induced buoyancy convection is suppressed, surface-tension-induced thermocapillary convection dominates in the molten zone. In floating zone crystal growth, thermocapillary convection can be strong enough to cause formation of dopant striations and a convex growth front - both are undesirable in crystal growth.

RESEARCH TASK DESCRIPTION

Small (e.g., 4 mm diameter) transparent floating zones of silicon oil and $NaNO_3$, in which thermocapillary convection dominates in 1g as in µg, are often used for flow visualization I ground-based experiments. However, these zones are noncylindrical in 1g and the flow pattern in the floating zone is distorted significantly by the lens effect of the transparent liquid. The tasks of the research were

1. derive analytical equations so that the lens effect can be taken into account,

2. study thermocapillary convection by flow visualization and computer simulation, and compare the two with the help of the equations.

ACCOMPLISHMENTS

1. Equations have been derived to relate the optical distortions caused by the floating zone to its refractive index and free-surface shape.

2. Computer simulation of thermocapillary convection has been conducted on: (a) a silicone oil zone, (b) a molten zone in an NaNO$_3$ rod, © floating zone crystal growth under µg (including thermocapillary convection, its interaction with crystal rotation, and their effect on dopant segregation in the resultant crystals).

3. Flow visualization of thermocapillary convection has been conducted on: (a) a silicone oil zone, (b) an NaNO$_3$ molten zone, and (c) NaNO$_3$ floating zone crystal growth.

4. Comparison has been made between calculated and observed: (a) flow patterns, and (b) velocity fields.

PUBLICATIONS

1. Lan, C. W., and Kou, S., Formulation for correcting optical distortions due to a transparent floating zone, Journal of Crystal Growth, vol. 132, 1993, p. 578.

2. Lan, C. W., and Kou, S., Radial dopant segregation in zero-gravity floating-zone crystal growth, Journal of Crystal Growth, vol. 132, 1993, p. 574.

3. Lan, C. W., and Kou, S., Effect of rotation on radial dopant segregation in microgravity floating-zone crystal growth, Journal of Crystal Growth, vol. 133, 1993, p. 309.

4. Tao, Y., and Kou, S., Flow visualization in floating-zone crystal growth, Journal of Crystal Growth, vol. 137, 1994, p.72.

5.  Tao, Y., Sakidja, R., and Kou, S., Computer simulation and flow visualization in a silicone oil zone, International Journal of Heat and Mass Transfer, vol. 38, 1995, p.503.

6.  Tao, Y., Xiong, B., and Kou, S., Thermocapillary velocity field in a silicone oil zone, International Journal of Heat and Mass Transfer, in press.